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Unmanned Air Vehicle Impact on CVX Design

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ADMINISTRATIVE INFORMATION

This study was prepared for the Naval Sea Systems Command (NAVSEA) CVX Program Office, PMS-378, by the Space and Naval Warfare Systems Center, San Diego (SSC San Diego) UAV Project Office.

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CONTENTS

FIGURES

TABLES

INTRODUCTION

The cost savings and risk reduction inherent in the use of unmanned air vehicles will eventually necessitate their integration into Navy and Marine missions. Maritime doctrine mandates independence from land-based assets to support these missions and thus unmanned air vehicles will by definition be organic to carrier and amphibious battle groups. The differences in sortie tempo and physical characteristics between manned and unmanned air vehicles favor shipboard separation of launch and recovery operations and a dedicated unmanned air wing. Potential reduction in manning and other cost savings associated with unmanned vehicles are realized at the squadron level (12 unmanned air vehicles).

BACKGROUND

The Naval Sea systems Command (NAVSEA) CVX Program Office, PMS-378, is conducting a series of trade-off studies to provide the necessary inputs for the creation of the Operational Requirements Document (ORD) for the Tactical Aviation (TACAIR) sea-based platform for the 21st century, the CVX. The Space and Naval Warfare Systems Center, San Diego (SSC San Diego) UAV Project Office has been assigned two of these studies. The studies revolve around identifying those "outer mold-line" design drivers resulting from having unmanned air vehicles embarked as part of the CVX air wing composition. These studies are sequential; the first addresses the issue of the missions that organic UAVs could perform while deploying from the CVX, and the second addresses the physical design impacts on the "outer mold-line" of the CVX if UAVs are integrated into the carrier air wing.

The current family of unmanned aircraft encompasses a broad category of airframes that include: remotely piloted vehicles (RPVs), unmanned air vehicles (UAVs), uninhabited combat air vehicles (UCAVs), unmanned aircraft, uninhabited aircraft, non-piloted aircraft, and drones. These are found in both the tactical and operational arenas. As the technologies and employment of these air platforms evolve, it is anticipated that a naming convention will eventually be adopted. For clarity in this study, these platforms will be referred to collectively as unmanned aircraft (UA). The functional distinctions between UAs are given in table 1.

Table 1. CNO SSG unmanned aircraft categories and functional descriptions.

Unmanned Aircraft (UA) Categories	Functional Descriptions
Remotely Piloted Vehicles (RPV)	Dependent systems requiring constant operator interaction.
Uninhabited Combat Air Vehicles (UCAV)	Semi-Autonomous. Can carry weapons or expendables. Although there is no remotely located pilot, human interaction required for critical events.
Unmanned Air Vehicles (UAV)	Non-weapons carrying platforms. Can be fully autonomous and may fly entire mission, including launch and recovery, without operator intervention.

STUDY SCOPE

This study is the second of the two studies, addressing general operational and physical design characteristics required to incorporate UAVs organic to CVX operations. Analysis includes both operations from a detachment standpoint (four airframes) and from a squadron standpoint (12 airframes). Potential impact areas include CVX deck structure, launch capabilities, recovery methods, maintenance spaces, storage spaces, personnel living spaces, command and control spaces and workstations, communications and data transmission paths, and ship antennae requirements.

This study was a 2-man-month level of effort. To maximize its effectiveness, several assumptions were made to allow focus on specific, critical areas. Additionally, the research methodology included review of existing literature and discussions with subject-matter experts to leverage existing studies and ongoing efforts within the Department of Defense (DoD) and industry. Deliverables from this effort included an annotated PowerPoint briefing package and a written report containing descriptive analysis of the CVX design "outer mold-line" drivers.

ASSUMPTIONS

The assumptions for this study were derived from initial guidance from the CVX Program Office and from research conducted for the study. The CVX Program Office set the target time frame for the study as the year 2013, which is the date that CVX is due to become operational, and the study team made additional assumptions regarding the employment of UAs. Specific assumptions include:

1. CVX will embark UA as a four airframe detachment or a 12 airframe squadron.
    - Embarking UA on the CVX was reason for the study.
    - Operating the UA as a four airframe detachment was decided upon as this was the minimum number of airframes recommended by General Atomic and is the standard detachment size of CV-6 Pioneer deployments. Additionally, the EA-6B and E-2C aircraft deploy with similar numbers of aircraft.
    - Operating the UA as a 12 airframe squadron was chosen as that is the standard size of an F/A-18 Hornet squadron.
2. UCAVs will be addressed in the CVW mix.
    - This was requested by CVX Program Office personnel during one of the CVX study reviews conducted at SSC San Diego.
3. Heavy fuel engines (HFEs) will be operational by 2013.
    - Discussions with several of the UAV contractors, including General Atomics and from the literature review (reference 1, UAV Annual Report FY 1997) indicate that HFEs will be fully operational by 2013. Testing of HFEs will take place by the end of CY 1998.
4. Tactical control stations (TCSs) will be integrated into CVX's combat systems.
    - TCS program specification is for it to be the common control systems for all medium altitude and endurance (MAE) UA (e.g., Predator) and tactical UA (e.g., maritime vertical takeoff and landing (VTOL) UAs).

5. UA will be an air wing asset.
   - This assumption was made in accordance with standard Naval Aviation Operating procedures for carrier-based aircraft.

Table 2 lists the presumed migration of the current usage and deployment of the various categories of UA as they relate to the postulated operating environment in the year 2013. The shift from the temporary research and development (R&D) and test and evaluation (T&E) installations to the permanent, integrated installations and deployments on the CVX requires a complete, end-to-end engineering solution. This will ensure complete integration and joint interoperability of the planning, control, and product dissemination portions of the installed UA system.

Table 2. Maritime UAV migration path.

1990s	2013
UAV – UCAV – RPV – NPV - MUAV – SRUAV – TUAV - Non-Manned – Lethal UAV– HAE – MAE	UAV – Unmanned Air Vehicles (Generic Term) [many sub-categories]
TCS/GCS/Antennas (temporary installations for short term operations, evaluations and tests)	Permanently integrated installations of payload/ airframe control consoles & Multifunctional Planar Antennae
Detachments and Temporary Presence	Full CVW Composite Squadron embarked

Note: See appendix C for definition of abbreviations.

STUDY PARTICIPANTS

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Mr. Estabrook currently serves as the Director of the SSC San Diego UAV Project Office and, as such, is involved in a wide variety of UAV-related projects in the C4ISR (command, control, communications, computers, intelligence, surveillance and reconnaissance) community.

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Robert Mac Dougall is a joint service operations and simulation training specialist with extensive expertise gained through operational Navy tours in the Navy's E-2C, in the USAF E-3 AWACS, a Third Fleet reserve Joint Forces Air Component Commander (JFACC) Operations and Plans Officer, and Amphibious/Littoral Operations Officer for Tactical Air Group-1 (TACGRU-1). In his 7 years at Tactical Training Group Pacific (TACTRAGRUPAC), Mr. Mac Dougall designed, developed, and participated in

over 500 computer simulation wargames using the Enhanced Naval Warfare Gaming System (ENWGS) to train all of Pacific Fleet's (PACFLT's) battle staffs. With AB Technologies, at SSC San Diego (D808) and Space and Naval Warfare (SPAWAR) Systems Command (PMW-132X), Mr. Mac Dougall tested, integrated, and developed the operational capability for the Common Operational Modeling, Planning And Simulation System (COMPASS) and conducted numerous field evaluations and assessments of C4I and modeling and simulation (M&S) technologies.

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Rick "Wigs" Ludwig is a former naval aviator with 28 years experience. Mr. Ludwig has commanded an F-14 Squadron, an Operational and Test Squadron, the Navy Fighter Weapon School ("Top Gun") and was CV qualified on four different aircraft, including rotary wing. After retiring from the Navy, Mr. Ludwig became a part of the team that developed the Common Operational Modeling, Planning And Simulation System (COMPASS) at SSC San Diego.

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Ms. Cook is assigned to assist researchers in the more progressive technical areas where information is not readily available. Ms. Cook is currently working to develop a UAV Reference Library that will reside in the SSC San Diego UAV Projects Office.

LITERATURE REVIEW

A wide-ranging review of UA literature discovered several applicable programs and studies. While the majority of the information available pertained to the UA airframe itself and the UA payload product dissemination to intermediate and end users, five major sources dealing directly with the issues of CV- and LHA-level integration of UA and their command and control (C2) and support systems were found. These are:

1. Chief of Naval Operations (CNO) Strategic Studies Group XVI Final Report
2. Office of Naval Research (ONR) 351 Future Air Ship Integration Technology Study (FASITS)
3. PEO (CU/UAV) Predator Marinization Study
4. General Atomics – Aeronautical Systems Inc. (GA-ASI) I-GNAT Study
5. DARO Force Structure Projection for 2010.

The results of each of these studies are summarized in the following sections.

CNO STRATEGIC STUDIES GROUP XVI

The CNO's Strategic Studies Groups (SSG) are tasked to identify technologies that will lead to emergent Maritime Strategy, and they serve as the nucleus for the generation of innovative concepts for future naval warfighting. The SSG is tasked by, and reports directly to, the CNO. The SSG's objectives include exploring innovations, developing warfighting concepts, pairing concepts to technologies, establishing evaluation criteria, and recommending actions to the CNO.

The SSG's Projection and Protection Concept Generation Team explored alternative means of both airborne power projection and combat support assets in the 2015 to 2020 time frame. Vertical takeoff and landing (VTOL) and vertical short takeoff and landing (VSTOL) uninhabited combat air vehicles (UCAVs) and support UAVs (SUAVs) were addressed in this study as a complement to traditional manned aircraft missions. The team focused on the increase in affordability, flexibility, and lethality of future naval forces through the use of these UAs. The CNO SSG XVI Innovation Concept Team Report of June 1997 (reference 2) provided additional guidance and scope for the development of various classifications of UA and their use within the carrier battle group (CVBG). SSG XVI also had a concept team focused on UAV employment and life cycle.

The SSG report addresses the impact of UAs on the composition of the embarked air wing as it relates to flight deck space available. The SSG team considered three variations of the current Tactical Air (TACAIR) strike capability and carrier air wing capability, as given in table 3.

Table 3. Manned TACAIR/UA mix in CVW employment.

	CVN/CVW (with near-term CVW)	**CVN w/SUAV** (circa 2020)	**Strike CVN** (SUAVs on DDG/DD)	**Strike CVN** (SUAVs on DDG/DD)
Total # aircraft onboard CV	75 (all manned, 20 support a/c)	87 (20 SUAV)	75 (all manned, all TACAIR)	87 (20 UCAV)
# of TACAIR on flight deck	36	48	54	63 (15 UCAV)

The first column (CVN /CVW) reflects the baseline configuration of a *Nimitz* class carrier with its 1990s air wing. It carries 75 manned aircraft, which includes 20 aircraft broadly defined as "support" aircraft. Columns two, three, and four show the configurations and relative on-deck advantage of the three variations.

There is also an advantage in the decreased weights between manned and unmanned airframes. The UCAV variants studied by the SSG were 50% less in weight than comparable manned aircraft. The overall weight savings of a few aircraft have little impact on the total tonnage of the CV itself, however, the resulting increase in flight deck weight bearing capacity supports the vertical stacking storage plans for the hangar bay without increasing the deck stress.

Unmanned Aircraft (UCAV and UAV) span the full range of risk and complexity, from a simple recoverable cruise missile to a complex air combat jet attack fighter such as envisioned in the UCAV concept. While the Army and Air Force focus exclusively on land based platforms, the Navy and Marine applications of UAs are more complex due to their need to launch and recover on ships. For this reason the SSG recommended the development of VTOL UAs. While VTOL UAs may be based on ships other than the CV, they may also be operated from, or controlled by, the CV while deployed. Thus, the development of UA VTOL variants does not completely obviate the impact of UA C2 and antenna integration on CVX design.

The SSG Report discussed the design advantages of UA over manned aircraft and concluded that they are promising solutions for affordably expanding the Navy's power projection capability. Advantages include the following:

- UAs offer lower life-cycle costs than manned aircraft.
- UAs offer design freedom to permit installation of airframe components for optimum functionality without concern for pilot-specific equipment placement. This results in lethal, survivable, and flexible platforms at a lower unit cost.
- UAs avoid pilot risk and can perform reconnaissance, deep strike, and lethal suppression of enemy air defenses (SEAD) at the earliest stages of conflict, clearing the way for manned aircraft.
- UAs change the calculus of attrition by making platform survivability and economics warfighting issues rather than the difficult issue of casualty reduction/elimination.

The design of UAs yields savings in deck space on the flight deck and hangar bay. By removing the cockpit occupants, life support, mission, and display equipment from the airframe—particularly in a multi-seat aircraft—a dramatic size reduction in the airframe will result. The SSG noted that a support UA will occupy roughly one-third of the deck space of its counterpart manned aircraft.

While the SSG recommends VTOL support UAVs, it acknowledges that UCAV variants would be handled more like conventional manned aircraft.

The underlying assumption of the SSG Concept Generation Team was that UAs would always be small enough to use non-catapult launch techniques and not require the arresting gear used by manned aircraft when operating from the CV. Historically, however, the evolution of aircraft shows that the weights of airframes tend to increase through the service life of the platform. It is not clear that UAs will be an exception to this trend. The proposed VTOL Strike UCAVs and Fighter UCAVs are designed near the edge of the flight envelope for non-assisted takeoff and landing and could quickly become heavy enough to require the use of the CV's launch and recovery systems. To plan for this growth, the CVX should consider building in the capability to launch and recover unmanned aircraft in the 3000- to 18,000-pound range.

If the UCAV concept develops into an operationally sound technology, and ongoing programs seem to indicate this is a distinct possibility (e.g., the USAF/Defense Advanced Research Projects Agency (DARPA) UCAV Program), the CVX design team should be prepared to incorporate this new capability into its mission.

ONR 351 FUTURE AIR VEHICLE/SHIP INTEGRATION TECHNOLOGY STUDY (FASITS)

The Office of Naval Research (ONR), Code 351, investigated the technical parameters, operational issues, and potential utility associated with the integration of weapon-delivering UCAVs onboard surface combatants in the 2010 to 2020 time frame. In support of this effort, Code 351 requested that the Naval Reserve Science and Technology Program, in cooperation with the Naval Reserve Air Systems Program, undertake a study to offer an operational perspective of future UCAV and ship integration challenges. The study reported its findings on 30 September 1997 (reference 3).

The ONR report defines a UCAV as an airborne vehicle design that captures the most relevant features of manned aircraft, weapons (missiles), and UAVs required to conduct cost-effective lethal combat missions. ONR 351 considers a UCAV as representing a fourth category of airframe combining the attributes of the other three. UCAVs could be based on land, the CVX, or other ships, depending on the airframe variant considered.

The hypothetical UCAV design concept represented in the ONR study is a vehicle that weighs close to 15,000 pounds and carries a weapons load of almost 2000 pounds (weapons plus sensors). The study described improved miniature conventional weapons in the 100- to 200-pound range that would have the increased accuracy and explosive impact of today's 2000-pound bombs.

Any newly developed aircraft must pass strict CV suitability standards for operational safety in the maritime environment. UCAVs present some peculiar problems because their size and performance characteristics fall in between the normally recognized performance envelopes of manned aircraft (generally weighing 20,000 pounds and up) and conventional/legacy UAVs (generally 5000 pounds and below).

Ship Integration Considerations

Ship integration considerations include:

- Recovery systems
- Launch systems
- Unit and ship manning requirements
- C2 system integration
- Hangar deck storage
- Antenna integration (including EMI/HERP/HERO)
- Support equipment
- Weight considerations
- Maintenance

- Training
- Operations safety

In the ONR FASITS Study, each of these areas is extensively discussed. No UCAV employment "showstoppers" were identified, but several items requiring additonal study, research, and development were identified.

Ship modification requirements identified by the study include:

1. Launch Systems
    - For non-VTOL capable (i.e., conventional deck running), a catapult system would be required.
    - On some CVX variant, a small jump ramp integrated into the flight deck might be employed.
2. Storage Space
    - UCAV-specific ordinance requirements do not vary significantly from current ordinance requirements and procedures.
    - UCAV deck multiples are lower than manned aircraft.
3. Control Consoles
    - Ship C4ISR systems and terminals must be modified to accommodate UCAV sub-modes. In some cases virtual cockpit capability is required.
    - Integration with fully joint C4ISR distributed collaborative planning architecture required.
    - Location of control terminal consider flight deck and hangar deck operations, taxi, and maintenance.

PEO (CU/UAV) PREDATOR MARINIZATION STUDY

The Predator Marinization Study (reference 4) identified the modifications that the Predator MAE UA System requires to operate in a maritime environment associated with operations from aircraft carriers (CV/CVN) and aviation-capable amphibious ships (LHA/LHD). This design engineering assessment developed top-level alternatives for major Predator System modifications required to produce a maritime variant of the Predator.

A specific effort was made to assess the aerodynamic design/performance enhancements required for the Predator. Special attention is given to alternatives that would not require, or would minimize, shipboard modifications.

Jet-assisted takeoff is the most practicable means to augment Predator acceleration for a free deck rolling takeoff. Shipboard arrestment is achieved through addition of direct lift control (e.g., spoilers) devices to the wings, a tail hook and trailing arm landing gear stressed to absorb impact from an 18-foot-per-second landing. A portable lightweight arresting wire system, similar to that developed for the Hunter UAV program, is required on the ship flight deck.

The Predator Marinization Study also outlines alternatives for several minor modifications to integrate the Predator System into carrier/amphibious operations and to enhance shipboard compatibility. The most significant of these modifications requires the addition of communication antennas for Predator

command/control and data links. Additionally, integration of the Common Automated Recovery System into the air vehicle and ship is required to minimize landing dispersion and improve all-weather recovery. In the interest of affordability, the study includes a Predator maritime variant that is shipboard-launched, recovered at a land base and returned to the ship in its container ready for use (e.g., limited setup and maintenance on ship).

The study also finds that shipboard Level 4 control of the Predator and its sensors and receipt of the UAV imagery may be a cost-effective alternative to full employment from the decks of CVX.

The feasibility assessment team was organized by disciplines into five teams:

1. Air Vehicle – responsible for carrier suitability assessment of the air vehicle's aerodynamic and structural design with respect to launch, recovery, and operational flight characteristics.
2. C4I – responsible for assessment of the Predator command, control, and data system integration into the CV/LH class ship communications suite.
3. Avionics – responsible for assessment of electrical, electronic, and electromagnetic (E3) hardness of the Predator System for shipboard operations.
4. Carrier Suitability – responsible for assessment of the Predator System suitability for integration into the CV/LH ship systems and capabilities.
5. Air Wing Operations – responsible for assessment of the Predator System integration into standard operating procedures aboard ship.

The Predator Marinization Study focused on identifying "showstopper" issues that require design change or modifications to allow the Predator System to operate in the CV/LH ship class environment. For each "showstopper" identified, a range of design alternatives has been developed to provide a choice of remedies. These issues are addressed in sufficient detail to allow a rough order of magnitude (ROM) cost estimate to be developed for most remedies. The issues are presented in following sections.

Issue: Launch distance/Wind over the deck (WOD) combinations required by baseline Predator exceed that available on CV and LH class ships

Marinization Requirements and Constraints. *Nimitz* class CVs provide approximately 1080 feet of deck run distance on the axial deck, approximately 350 feet ahead of the bow jet blast deflectors, approximately 785 feet on the full angle deck, and approximately 500 feet on the angle deck ahead of the arresting pendants. Making the entire axial deck available for Predator operations would have a severe impact on air wing operations. In routine operations, these ships can be expected to provide up to 25 knots WOD on a calm day. The LHA and LHD classes provide approximately 800 feet on their axial decks and 15 knots WOD.

Shipboard performance calculations for Navy aircraft are normally quoted at tropical day (90 degrees) conditions. Fleet experience over the past 60 years has determined that many uncontrolled variables occur during aircraft launches. To accommodate these variables, fleet operators routinely add a safety margin of 15 knots to minimum launch speed. This assessment assumes that the same experienced-based caution is applicable to Predator.

Current Capability and Potential Marinization Issues. The baseline land-based Predator with full fuel and 450 pounds of payload requires over 3000 feet to take off with zero wind and over 2000 feet with 15 knots of headwind. These values are for the tropical day but do not reflect any operational WOD

margin. In addition, these values do not reflect the impact of additional weight necessitated by other changes required for marinization. These values substantially exceed what is available for CVs or LHs.

Areas of Impact and Potential Alternatives. If launch distances cannot be reduced sufficiently, Predator cannot be launched from either CVs or LHs. Potential alternatives include:

1. Exploiting "sink off the bow" techniques that allow the aircraft some additional acceleration to fly-out speed after the end of the deck is reached.
2. Trading off fuel load (and therefore endurance) or payload to reduce distance by reducing launch weight.
3. Increasing the high lift capability by addition of flaps to reduce launch speed required for a given weight.
4. Increasing the acceleration capability of the aircraft. Means to achieve this include increased engine power, use of the CV catapults at low-capacity selector valve settings, use of jet-assisted takeoff units, and use of a sailplane-type launch winch.

Issue: LOS and BLOS Command and Control and Data Relay

The Predator UA uses a C-band analog, 5250 to 5850 MHz, data link for line-of-sight (LOS) C2 and data relay, and a Ku band digital, 11450 to 14500 MHz, satellite link for beyond line of sight (BLOS) C2 and data relay.

For LOS control, the only viable option is to install three C-band antennas (one directional and two omni-directional) on board. For BLOS control, the recommended alternative includes:

- Delay air vehicle Ku-band signal through a ground station, separating the C2 signal out for delivery via two-way C (Challenge Athena) or X (DSCS) band signal.
- Deliver the imagery portion via one-way Ku Joint Broadcast System signal or Ka Global Broadcast System signal.

An alternate choice is to use the air vehicle UHF SATCOM link for two-way C2 link and the Ku SATCOM link, via ground relay conversion to C-band Challenge Athena or X-band SHF, for one-way imagery and telemetry link

Issue: Predator engine fuel (AVGAS) not suitable for shipboard use.

Marinization Requirements and Constraints. Shipboard-compatible aircraft must use the existing ship's fuels (JP-5) if large quantities are required to perform the mission.

Assessment of Alternatives. Incorporation of a heavy fuel engine into Predator provides the least impact to the ship and shipboard operations.

Issue: CV Class ship catapults not designed or tested for aircraft as light as Predator.

Marinization Requirements and Constraints. The installed catapults are designed to launch much larger aircraft that sustain greater accelerations to achieve higher end speeds. Predator cannot accept these forces without structural failure.

Current Capability and Potential Marinization Issues. It may be possible to use the existing catapults for a Predator modified to accept higher stress loading. Lowering the catapult receiver pressure from approximately 450 psig to approximately 100 psig through a catapult accumulator "blowdown"is a standard procedure. Blowdown to the lower pressure should take about 35 minutes (about 10 psig per minute). Recharging to the normal operating pressure should take about 30 minutes using the standard procedure. These procedures are fairly conservative and it may be possible to alter them to make the process faster. For example, the catapult at Lakehurst was blown down in about 15 minutes. A hookup and holdback device as well as a bridle device would need to be designed for Predator. It is estimated that a bridle and holdback modification for Predator will cost NRE $372,000; RE cost per air vehicle $13,000.

As the aircraft is not designed for launching from a catapult, it will be necessary to redesign the landing gear to use a larger wheel and to be capable of accepting a bridle. The current nose wheel is so small that it is highly probable that it will jam in the catapult slot, which may be as wide as 2 inches. The aircraft may yaw during a catapult launch, causing the nosewheel to move across this slot.

Given that the current brakes will not hold the aircraft at full power, a "hold-back" device will be required to allow the engine to reach maximum output power prior to beginning the takeoff roll. Padeyes may be used as tiedown fitting for holdback securing.

A bridle device will need to be developed to allow hookup to the catapult.

Areas of Impact and Potential Alternatives. Further development and testing of procedures for using C-13 catapults at lower pressures is required to determine applicability. Bridle and hold-back hardware will need to be developed.

Assessment of Alternatives. With new procedures and modifications mentioned above, it may be possible to use existing catapults to launch the Predator; however, any catapult launch will exceed the g-load limitations even using the most conservative settings. Extensive testing will be required to determine the feasibility of this alternate method. Early tests indicate potential problems with bridle shedding. Further tests are required. Other approaches for takeoff are presented in the Air Vehicle section of the Predator Marinization Study (reference 4).

Issue: Installed arresting gear (MK 7) not compatible with aircraft as light as Predator.

Marinization Requirements and Constraints. The installed arresting gear is not usable due to the mass of the cross deck pendants (CDP) and arresting gear machinery.

Current Capability and Potential Marinization Issues. The MK 7 - Mod 2 arresting gear cross deck pendants (CDPs) are 1 3/8 inches in diameter and extend 120 feet across the landing area of the angle deck. The CDPs are supported 4.5 inches above the flight deck by spring supports. The CDP can be disconnected at either or both ends to clear the flight deck area. CDPs are routinely replaced in 5 minutes during recovery operations. All four can be "derigged" to provide a clear landing area for takeoff or landing roll out. There are four spring supports spaced across the landing area for each CDP, which can

be removed. The existing arresting gear engine and the shear weight of the CDP is not consistent with arresting light aircraft such as the Predator.

Removal and replacement of the existing four CDPs would take approximately 9 minutes; 4 to remove and 5 to replace. This involves detaching the pendants from one side and moving them to the other.

The CDP supports are arched springs held in tracks fixed to the flight deck. The springs are several feet long and about 4.5 inches high at the top of the arc. The lifting force available is about 200 pounds. The supports are not actuated in any way. The inboard rows of pendant support are about 13 feet from the recovery centerline. The inboard rows of support (totaling eight supports) can be removed in about 10 minutes. The next rows of support are another 15 to 20 feet outboard of the inner rows. Removing the inboard rows gives a total clear span of at least 56 feet (28 feet each side of the recovery centerline). Removal of the CDP supports will be time-consuming and is inconsistent with flight deck readiness.

No data are available as to the time required to install and remove a modified Hunter-type arresting gear system.

Areas of Impact and Potential Alternatives. The Hunter UAV used a friction brake arresting gear system chained to the deck with a standard TD-1A deck tie-down chain for shipboard demonstrations. The arresting gear used a simple disk brake mechanism attached to a spool that held a nylon webbing purchase cable. The cross deck pendant was nylon cord with rubber disks on the cord to elevate it above the deck for tailhook engagement. Hunter arresting weight was about 1300 pounds at about 60 knots. Runouts were expected to be between 100 and 250 feet depending on the variations in weight, wind over the deck, and approach airspeed. The Hunter gear was adjustable, and it may be possible to adjust it to accept the landing weights and speeds of Predator. TRW, the designer of the Hunter, was developing a new friction brake arresting gear system that incorporated a number of improvements. The new system would have been more suitable for shipboard use. TRW personnel have stated that the new arresting gear system could easily be modified to accommodate Predator weight and speed requirements. Their rough order of magnitude cost estimate of completing the modified design is $140,000 per ship unit.

Another type of commercial off-the-shelf (COTS) arresting system uses "water twisters" to provide arresting force. It may be possible to incorporate minor modifications to an existing water twister design to meet Predator's requirements.

The number of CDPs available will affect the precision required for landing. Having fewer pendants requires greater landing precision but takes less time to install. The gear should be positioned in the landing area commensurate with a 4-degree glideslope and hook-to-ramp clearance of 10 feet. Experienced Predator pilots have reported that the air vehicle can be landed repeatedly in a 20- by 20-foot box. The pilot believes similar landing dispersion can be achieved shipboard with sufficient practice.

The portable arresting system may also be located forward of the landing area, thus avoiding the need to remove the MK 7 CDP prior to recovering Predator. This may be advantageous when manned aircraft are airborne. Deck space available and runout for Predator is discussed in reference 4, appendix F.3.

Assessment of Alternatives. The existing Hunter arresting gear should be investigated for applicability to Predator. It is not clear that the system has the desired energy absorption capability for Predator. The Hunter brakes are a proven system, are man portable and are easily deployed.

The possibility of continuing development of a Predator-specific arresting gear system should be investigated. Friction brakes are generally light and man-portable.

Water twisters provide a more consistent runout distance than friction brake systems. However, water twisters are heavier than friction brake systems, and would be more difficult to deploy for each operation.

Portable arresting gear would provide arrested landing capability on LH and CV/CVN ships. Locating the temporary arresting gear forward of the normal landing area results in insufficient deck run for bolter. Additionally, the assistance from the Landing Signal Office (LSO) and fixed landing reference systems is reduced. The physical location of the common automatic recovery system (CARS) flight deck equipment becomes difficult.

Issue: Predator wheels may be too small relative to flight deck obstructions.

Marinization Requirements and Constraints. Fixed obstructions on the flight deck may cause damage to or effectively block Predator wheels and landing gear structure during touchdown or at high speeds.

Current Capability and Potential Marinization Issues. The flight deck has various fixed obstructions such as light fixtures, catapult shuttles, catapult hookup areas, tie-down fittings, catapult shuttles, and camera fixtures that could damage the landing gear. Pendants and wire supports will have to be removed from the landing area for a free recovery.

Areas of Impact and Potential Alternatives. The UAV will need to have landing gear with wheel size suited to withstand impact with flight deck obstacles during recovery.

Assessment of Alternatives. Failure to provide adequate strength in the landing gear will result in failures during recovery, possibly causing significant damage to other embarked aircraft.

Issue: Predator shipping crate and special handling equipment require adequate storage.

Marinization Requirements and Constraints. With storage space at a premium, tradeoffs with existing uses of storage spaces will have to be made to allocate available space for storage of Predator-unique equipment.

Current Capability and Potential Marinization Issues. The shipping crate is large and adequate storage space in the hangar bay will have to be identified. Special ground support equipment and unique spare and repair parts will likewise have to compete with other aircraft equipment for storage space. Ground support equipment associated with the present Predator system is described in reference 4, appendix D.2.

Areas of Impact and Potential Alternatives. Incorporation of Predator on an operating ship will require tradeoffs with existing air wing equipment. Provision would have to be made for a Predator "mission pack," which would include the shipping crate required to on load-off load the UAV, ground support equipment, and spare and repair parts unique to the aircraft. Other administrative, maintenance, and personnel space would have to be made available for the Predator support personnel.

It may be possible to keep only one container onboard the ship and rotate containers on and off with their aircraft as needed.

Issue: Predator operational maintenance aboard ship must be compatible with Naval Aircraft Maintenance Program and shipboard aviation facility capabilities.

Marinization Requirements and Constraints. Shipboard aircraft must be as compatible as possible with existing aviation maintenance facilities to minimize integration problems. In so far as practicable, the requirements specified by the Naval Aircraft Maintenance Program (NAMP) are applicable.

Perhaps most critical in Predator CV/LH Class deck operations is the transition from air vehicle operation (AVO) vehicle control when flying to positive control by the deck crew once the vehicle has arrested. This responsibility shift is dangerous since airborne control ceases on landing rollout, but the deck crew must chock the aircraft, tie it down, remove the wings, and tow it clear of the landing area. Once engine shutdown occurs, the AVO can no longer control the vehicle and communication among the deck crew is critical. The procedure for accomplishing this critical exchange of control is discussed in reference 3, appendix G. Alternative ways to accomplish this procedure will be developed when Predator is actually handled in the flight deck environment.

Recommendations (Shipboard Compatibility)

Fuel. A heavy fuel engine is defined as a requirement for marinization. Based on the extreme safety hazards associated with low flash point fuels, a heavy fuel engine is recommended for this air vehicle.

AVGAS Redesign/Alternative. If an AVGAS air vehicle is retained, redesign or an operational alternative that may impact safety, storage, and logistics plans and policies is required. Provision for additional or larger fuel storage facilities, safety features such as jettison platforms, and increased logistical support will have a major impact on operational support, ship design, and overall costs.

Tie-Down Points. Tie-down points must be provided to safely secure the aircraft on the moving flight deck. Tie-down points should be added to the main landing gear, nose landing gear, fuselage, and the wings. A method of safely and quickly removing, attaching, and transporting the Predator wings should be developed.

Maintenance Plan. A maintenance plan must be developed and appropriate gear defined.

Portable Arresting System. A portable arresting system similar to that developed for the Hunter JTUAV is recommended for use with the marinized Predator notionally described by the Air Vehicle team. The ability to use this system for both CV and LH Class ships is important.

Storage of Predator Components on Hanger Deck or Vehicle Storage. One complete air vehicle comes in a single transportation container. Each container is 32 feet 3 inches long, 4 feet 6 inches wide, and 4 feet 1 inch high on a retractable 7-inch wheel assembly. A full container weighs about 4000 pounds. The container weighs 1500 pounds empty, with a removable 450-pound top. The containers can be stacked two high and has lifting and tie down points. These containers may be brought aboard dockside by crane (see Note below) or at sea vertical replenishment or boats for the LH class. Carrier on-board (COD) service is not feasible due to the length of the container. Once aboard, the container, full or empty, will be handled with the equipment and procedures similar to those utilized for spare aircraft engine containers.

Other recommendations to improve the Predator Air Vehicle carrier suitability are in the Air Vehicle section of reference 4.

GENERAL ATOMICS – AERONAUTICAL SYSTEMS INC. (GA ASI) I-GNAT STUDY

GA-ASI studied the modification (marinization) of its Improved GNAT (I-GNAT) UAV surveillance system for operations from CV and LH class vessels. This program is already included in an joint and Naval Advanced Concepts Technology Demonstration (ACTD) of an enabling technology.

A marinized I-GNAT would carry a minimum 300-pound payload with an endurance of over 16 hours. The airframe could recover without using CV conventional arresting gear if the full axial deck was available. Angle deck length, bolter, and safety considerations make using the CV's angle deck and arresting gear preferable. Marinized I-GNAT would include TCS Level 4 and Level 5 controllability features. The I-GNAT will incorporate the proposed heavy fuel engine (HFE) required for CVX basing. The I-GNAT would also include the use of the carrier automatic recovery system (CARS) for assisted recovery on the CV and LH class vessels.

The GA-ASI study detailed the technologies addressed by the employment of the I-GNAT System and described technical characteristics of the evolving platform.

DEFENSE AIRBORNE RECONNAISSANCE OFFICE (DARO) FORCE STRUCTURE IN 2010

The DARO UAV Annual Reports from 1996 and 1997 (references 1 and 2) are informative single-point resources on all current Approved Acquisition Programs (formerly Programs of Record) and near-term service plans. The 1997 UAV Annual Report identified numerous other resources and agencies that were consulted for the study. The DARO Reports also highlight the myriad of terminology used to describe the various missions, airframes, control devices, and other phraseology used by the professionals in the field of unmanned aircraft. DARO also presented its vision for the exploitation of UAV technologies at the UAV Battle Lab Symposiums held in 1997 and 1998.

For naval operations, two different sets of assumptions with respect to the mix of aircraft within the CV's air wing were discussed. These assumptions were offered conceptually and did not include specific cost trade-offs.

1. Add UAVs to the current air wing and change the mission mix of manned aircraft. This is built on the assumption that UAVs were normally smaller (approximately 50% deck multiple) than conventional manned aircraft. This discussion centered on a shift of mission from manned aircraft to unmanned aircraft.
2. Add UAVs to the composite CVW and thus add even more JSFs to flight deck. This assumption echoes one from the UAV Strategic Studies Group by describing how adding UAVs to the CVW will shift some missions assigned to the JSF to UAVs. This results in more of the JSFs on the flight deck being directly allocated to strike missions.

Additionally, DARO discussed the integration requirements of the UAV planning systems with the force C4ISR. Current UAV C2 systems are stand-alone, and DARO continues to support full integration of UAV systems and products into the future distributed reconnaissance infrastructure (DRI) and other network-centric architectures.

UA AIRFRAME AND PAYLOAD CONTROL

In describing "control" of unmanned aircraft and the product of the payload, one's point of view must be taken into account. Current and future technologies allow for various levels of control of a given unmanned aircraft system. Effective operational and tactical use of an Unmanned Aircraft does not necessitate actual manipulation of the airframe or payload. As battlegroup operations move from a platform-centric to a network-centric environment, direct access to the raw data stream from an airborne payload may not be required. In many cases, the fully analyzed and assessed intelligence is the product the warfighter requires to enhance his operational decision process. To level the playing field for the description of UA control, the following five levels of control have been defined and promulgated by the UAV Joint Project Office. Table 4 is drawn from the UAV Annual Report of 1997 (reference 2). The control levels are cumulative in nature in that Level 2 implies inclusion of Level 1. Level 4 implies inclusion of Levels 1,2, and 3, and so on.

Table 4. TCS methods of control.

CONTROL LEVEL	DESCRIPTION	REMARKS
1	Receipt and transmission of secondary payload imagery and/or data.	End user has no control over airframe or payload.
2	Direct receipt of payload data/imagery.	End user has no control over airframe or payload.
3	UAV payload control and direct receipt of payload data/imagery. No airframe flight control.	Used to redirect or refocus a payload of a long duration mission while on orbit. Partial TACON.
4	Control of the UAV, less launch and recovery, in addition to all functionality of Levels 1 through 3.	Full tactical control (TACON)
5	Full functionality and control of the UAV and payload from launch to recovery and all mission aspects.	Operations control (OPCON) and TACON

These distinctions are important when determining the amount and type of equipment to be installed at the end user's location. The CVX Program Office's requirement is for Level 4 and Level 5 control. This will ensure full accessibility for the CVBG when using non-organic Unmanned Aircraft and for full OPCON of CVX-based UA.

There are varying amounts of impact the incorporation of UAs will have on the CVX design:

Level 1 – no change over current CV configuration

Level 2 – UA-specific antenna may be required

Level 3 – TCS required, increase to CVX combat systems footprint

Level 4 – GCS required, increase to CVX combat systems footprint

Level 5 – CVX recovery system modification required in addition to Level 2,3,4 additions

CVX SPACE CONSIDERATIONS

A consideration for the incorporation of UAV operations on the CVX will be the assignment of spaces. This assignment will be both for the maintenance and administration space requirements of the UAV unit and the control stations for the airframes and payloads.

Figure 1 depicts the interrelationships between the primary UA functions (airframe control, payload control, and mission planning) and the primary C4ISR nodes on a CVX that the UA systems will have to integrate with (feed). This is not to lead one to believe that these nodes be co-located. Quite the opposite is true. Those involved in the planning and control of UA must be separated from the users of the disseminated payload products. Requests for refinements to the UA route or changes to the route must come through normal C4ISR channels vice in person. UA missions require maximum focus and minimum distraction. A separate space with robust connectivity to the above-depicted nodes is required. The general flow and dissemination of UA products is standard within the C4ISR community, while the exact location of the UA space will be with the designers of the CVX. With IT-21 LAN connectivity, there is no reason for the receiving nodes and the UA "mission control space" to be co-located. The center of Figure 1 does represent the number of TCS type stations for the control of the UA system. Ten workstations will allow room for two mission planners connected those in CVIC, two level 5 airframe control workstations, and the ability to control three to four different payloads on missions. This assumes that the airframe stations have associated payload control stations integrated with them though the diagram above indicates payload control separated.

Figure 1 is also representative of a functional view of the control and planning stations when embarking a full UA Squadron level of effort. This separate space will nominally house 10 consoles for planning missions, flying airframes, and manipulating the payloads. This console footprint includes the following assumptions:

- 12 airframes embarked.
- Normal maximum airborne at one time would be six.
- Aircraft Control Stations can manipulate up three to four airframes at a time. This is in concert with the current 5:1 aircraft to controller ratio used for air intercept and air traffic controllers.
- Payload operations, being more intensive, have a 1:1 ratio of payloads to controllers. This console also conducts initial value-added intelligence screening of raw data from the payload.
- Mission Planning Stations will not be stand-alone, but integrated into campaign and tactical mission planners in use in 2013 such as the Joint Mission Planning System (JMPS).

Another possible variation would be to place the aircraft control and payload control stations within the existing structure of CIC (figure 2). This would closely mimic the placement of Air Intercept Controllers in the Air Control Module of CIC in function and overall command and control flow. It would also allow for routine airspace deconfliction within the area of operations, a function already performed in CIC. In this variation, the UA Control Module is a sub-set of CIC and the Mission Planning consoles would be located in the CVW/Strike operations and Intelligence planning spaces. This variation assumes the eventual merging of the present stand alone UAV mission planning capability within the fully joint and interoperable GCCS/TBMCS/CTAPS/TAMPS/AFMSS/SOFPARS/C4ISR distributed collaborative planning environment.

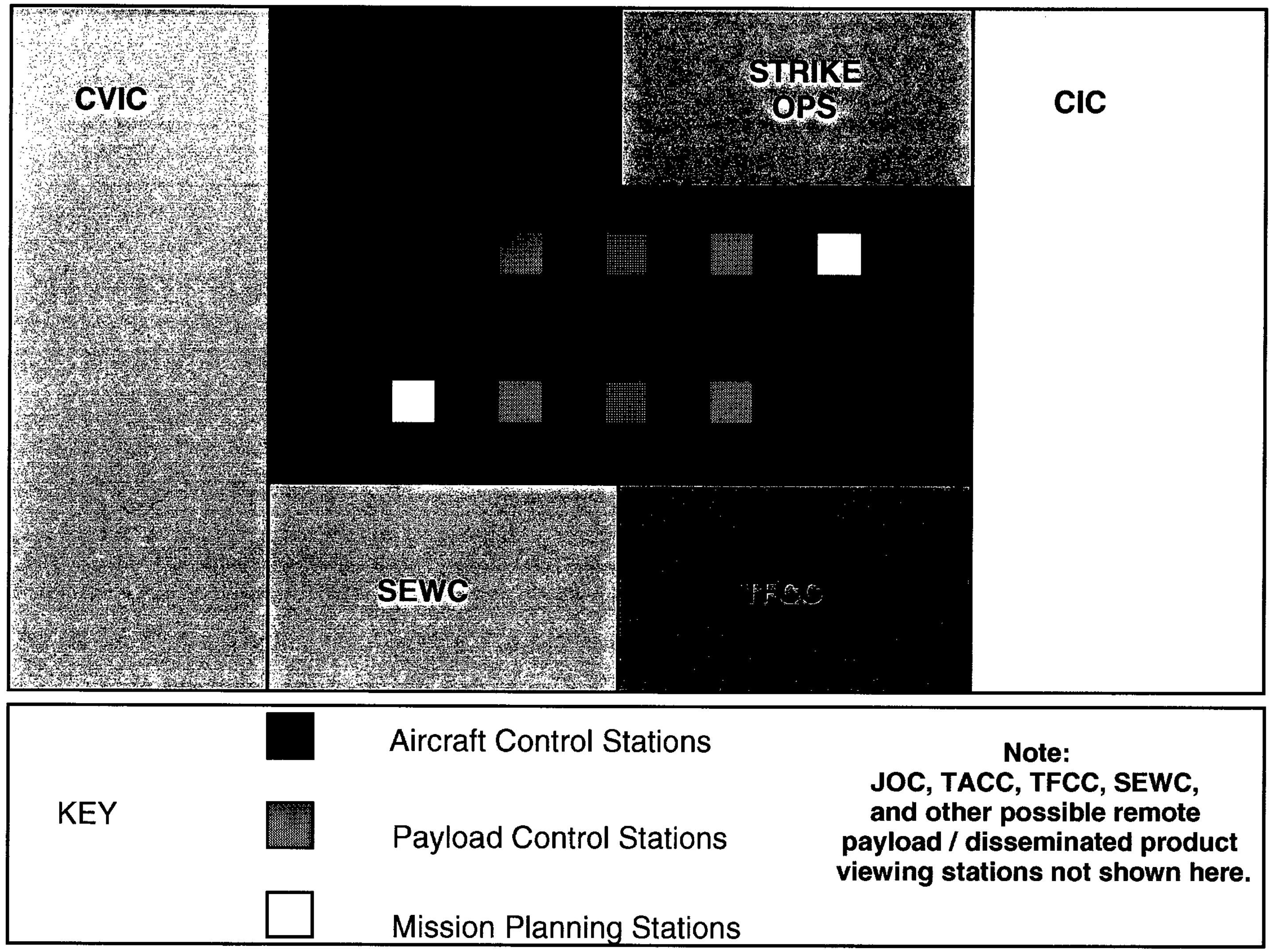

Figure 1. Notional UAV C2 space and C4ISR relationships.

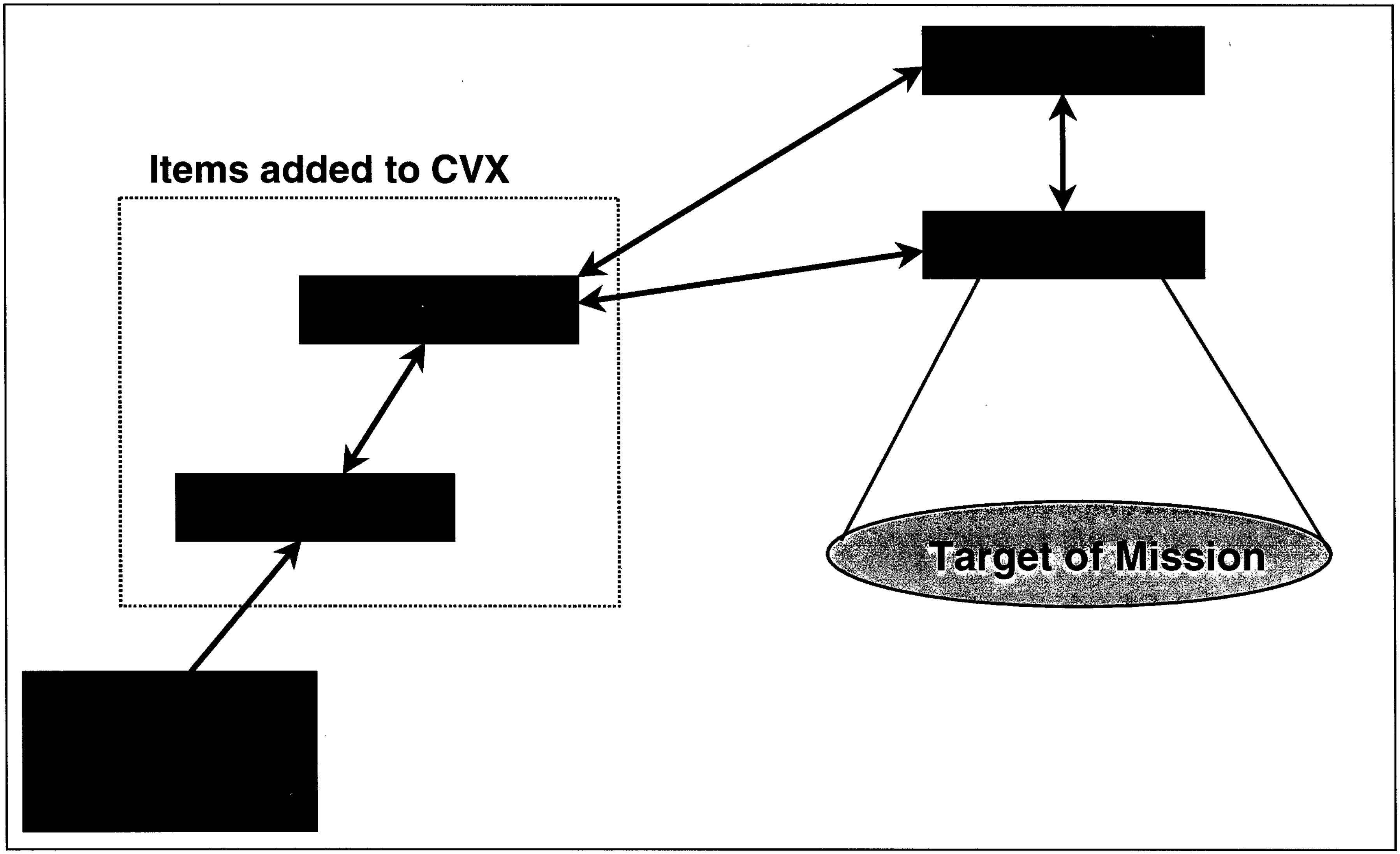

Figure 2. C2 integration.

Figure 2 does not address the value-added intelligence and analysis added to the payload products once the payload operator has accomplished the initial assessment. Current TCS and GCS systems being developed allow for some initial assessment to be done at the payload control station. Once the information from the UA is passed into the C4ISR network, it can be sent to any user, at any level, at any location.

This approach to AV and payload control is an extrapolation based on current thinking and funded methodology. It would behoove the Navy to examine this approach closely and, perhaps, modify it in an effort to separate the pilot and payload operator from the control stations. The use of autonomous flight control and planned integration of assisted target detection would be a step toward AV and payload control being an integrated segment to any workstation, or better, resident on a central server, thus further reducing the number of personnel required and the number of workstations depicted in figure 1. An additional benefit to this is that all warfare specialties can now access and work with AVs to tailor the mission to their needs.

Another impact of flying multiple AVs is being able to handle the amount of information, both in the downlink and in subsequent dissemination. Currently, the amount of video simultaneously being transmitted from several AVs would overwhelm the available bandwidth, even with RF spectrum managers in place. This begs for intelligent on-board processing with smarter sensors and the ability for assisted target detection.

The final major impact of current methodology is the lack of an approach to store and catalogue AV sensor information in a way that is easily accessed and searched by the warfare specialties.

As stated previously, it was outside the limited scope of this report to delve into the existing AV development programs and the associated C4ISR considerations. The purpose of this report is to examine the physical impact of bringing AVs on board CVX in terms of outer mold line drivers ("long poles in the tent").

CVX SHIP SPACE CONSIDERATIONS

There is a space trade-off with respect to manned and Unmanned Aircraft. If, as the CNO SSG suggests, 20 to25 UAs will replace a squadron of manned aircraft, a change in ship's space usage would result. The UA squadron would not require the spaces used by the manned aircraft squadron to support aircrew flight system and flight gear. This reduction is offset to some extent by the need for the UA squadron to have a series of control and operations terminals (TCS/GCS) that are not required by manned aircraft squadrons. Quantifying the potential offset was not within the bounds of this study.

Some of the TCS/GCS terminal footprint could be combined with existing C4ISR workstation footprints. However, there will be some TCS/GCS terminals that cannot be integrated into existing terminals or workstations. The UA aircraft control and payload control stations would represent an increase in combat systems footprint for the CVX. TCS/GCS terminals are presently evolving as dedicated terminals to control and operation of UAs. They are single-purpose terminals. The mission planning aspects of UA operations could be combined with the proposed C4ISR systems being developed. In the CVX, the mission planning function should be integrated with the JMPS distributed collaborative planning environment, allowing a full integration of UA operations into CVX operations.

MANNING

Table 5 provides a shipboard manning comparison.

Table 5. Shipboard manning comparison.

SQUADRON	# Aircraft	Officers	Enlisted	Remarks
F-14	14	33	250	
F/A-18E/F	12	25	185	
E-2C	4	28	130	
EA-6B	4	25	150	
S-3B	8	38	192	
ES-3A Det	2	7	30	
UAV	4	4	13	(Detachment – Routine)
	4	11	28	(Detachment – 24-Hr Ops
	12	33*	84	(Extrapolated)

RESULTS AND CONCLUSIONS

Integration of Unmanned Aircraft into the carrier air wing will produce savings in a number of categories. Examples include numbers of people, number and size of spaces, deck spotting factor (i.e., smaller footprint), and maintenance and support complexity. The extent of the savings has to do with the missions that UA can perform in lieu of manned air wing aircraft. A separate study is researching this aspect of UAs aboard CVX. The results of that study will be required to assess the extent and nature of the potential savings.

Larger Unmanned Aircraft will require energy assisted launch and recovery systems comparable to that of manned aircraft. The current launch and recovery systems and those projected for the future are not assessed to be compatible with UA-sized vehicles and structural loading. Potential solutions to this issue are either re-engineering the launch and recovery system for CVX or design future UA or redesign existing UA (Predator = maninization) to withstand the loading of the systems.

RECOMMENDATIONS FOR FURTHER STUDIES

An observation made during the study was that savings could be achieved in the realm of space and personnel by embarking UAVs onboard CVX. The time and scope of this study prevented the team from delving into the details of the potential savings. Further study into this area is recommended to quantify the savings in terms of dollars and personnel.

Mission definition of the Unmanned Aircraft requires further in-depth study to determine the exact extent to which UA can perform missions in lieu of manned aircraft. Furthermore, this should include the level to which UA may integrate with air wing tactical missions. At present, UA are primarily considered a reconnaissance asset. NSAWC has ongoing work examining the tactical integration of UA into CVW operations. This study merely took two scenarios to look at the numbers of UA on a CVX, four aircraft, and 12 aircraft. The appropriate numbers will require this additional study.

Control of UA relys on robust C2 connectivity. The core of this connectivity is the antenna architecture on the facility supporting UA operations. With the thrust of future surface platforms being signature reduction, it is imperative that future antenna design and structure be well planned. Planar multi-mode antennas incorporating low observable technology require further study to insure no stand-alone structures, signature control, and robust control of the vehicle operating within LOS at all altitudes and all points of the compass (i.e., ship superstructure must not degrade UA control).

With UA of long endurance capability such as the Predator (>30 hours loiter), integration/interleaving into CVW cyclic operations is not required. The airframes may be launched prior to the commencement of CVW operations and recovered after conclusion. If UA, such as UCAV, begin truly integrated operations with CVW manned aircraft, further study is required to determine the best approach including the advantages and limitations.

Lastly, it is recommended that an in-depth look at the ramifications of current AV and payload control and associated information management be undertaken. The role of C4ISR may not be an outer mold line driver, but it is a driver in the effectiveness of AVs in the conduct of the CVX mission.

REFERENCES

1. DARO. *UAV Annual Report 1997.* 6 November 1997.
2. *Naval Warfare Innovation Concept Team Reports.* Chief of Naval Operations Strategic Studies Group XVI. June 1997.
3. Dept. of the Navy, Office of Naval Research (ONR 351). *Future Air-Vehicle/Ship Integration Technology Study, 30 September 1997*
4. Engel, Kurt, CDR, USN, *Predator Marinization Feasibility Study.* Dept. of the Navy PEO (CU/UAV). 1 October 1996.
5. General Atomics - Aeronautical Systems Inc. (GA-ASI) I-GNAT Study
6. DARO. UAV Annual Report 1996. 6 November 1996.

APPENDIX A: COMMANDS, AGENCIES, AND INDUSTRY POCs

ENTITY	NAME	PHONE/E-MAIL	NOTES
AAI Corp. (Pioneer)		410-771-6200	
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Bell Helicopter Textron (TUAV)		817-280-3845	
Center for Naval Analysis	Ms. Ann Miller	703-824-2257	
COMNAVAIRPAC	Mr. Bill Clark Lcdr. John Sheehan Capt. Trey Ustik Capt. Bob Keeper Lcdr. Jerry Neuberger Lcdr. Gordy Spires	619-545-1407 619-545-4337 619-545-4350 619-545-2788 619-545-2027 619-545-1556	Science Advisor F-14/UAV N2
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Navy Unmanned Aerial Vehicles Program PMA-263	Capt.Tim Hallihan, USN	703-604-0883	
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PEO (CU/UAV)	Maj. Franklin Crawford	301-757-5837	UCAV
PEO (CU/UAV)	LTC Michael Bednarek	301-757-5835	
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APPENDIX B: BIBLIOGRAPHY

Annati, Massimo, *UAVs for Maritime Warfare.* Military Technology June 1997: p. 54-60.

Bennett, Jim, and Bill Walker, *Payload Integration Handbook for the UAV-SR Hunter System.* U.S. Army Systems Integration Laboratory and the UAV Project Office. January 1997.

Carmichael, Bruce W. (COL, USAF), *StrikeStar 2025.* Air Command and Staff College, Maxwell AFB. August 1996.

Center for Strategic and Budgetary Assessments. *Unmanned Aerial Vehicles: Current Plans and Prospects for the Future.* Backgrounder 11 July 1997.

DARO. *UAV Annual Report 1996.* 6 November 1996.

DARO. *UAV Annual Report 1997.* 6 November 1997.

Defense Airborne Reconnaissance Office (DARO). *Unmanned Aerial Vehicle (UAV) Program Plan.* April 1994.

Dept. Of the Navy PMS-378. *Operational Requirements Document for the 21st Century Tactical Aviation Sea-Based Platform CVX. (Draft)* 14 April 1998

Dept. of the Navy, Commander Third Fleet. (Tactical Memorandum TD0010-1-97) *CV-Based Aircraft in Support of Maneuver Forces (DRAFT).*

Dept. of the Navy, Office of Naval Research (ONR 351). *Future Air-Vehicle/Ship Integration Technology Study.* 30 September 1997.

Dept. of the Navy, PEO (CU/UAV) Joint Project. *Tactical Control System Statement of Objectives.* 14 January 1998.

Dept. of the Navy, PEO (CU/UAV) Joint Project. *Tactical Control System Hardware Performance Specification (DRAFT).* 24 February 1998.

Dept. of the Navy, PEO (CU/UAV) Joint Project. *Unmanned Aerial Vehicle Tactical Control System (UAV TCS) Test and Evaluation Master Plan.* Version 2.0.1, 15 December 1997.

Dept. of the Navy, Program Executive Office, Cruise Missile Project and Unmanned Air Vehicles Joint Project. *Operational Requirements Document for the Unmanned Aerial Vehicle Tactical Control System Version 5.0, with numbered requirements.* The Charles Stark Draper Laboratory, Version 1.0, 7 July 1997.

Dept. of the Navy. *Future Aircraft for Next Generation Ships.* Office of Naval Technology, Naval Air Development Center (NADC), Naval Air Engineering Center (NAEC). 1991

DoD, *Unmanned Aerial Vehicle (UAV) MasterPlan.* 15 April 1992.

Endacott, Steven, *USN UAV CONOPS.* Naval Strike and Air Warfare Center, 11 February 1998.

Engel, Kurt, CDR, USN, *Predator Marinization Feasibility Study.* Dept. of the Navy PEO (CU/UAV). 1 October 1996.

Erwin, Sandra, *Design of Next Generation Navy Carriers Driven by Need to Cut Crew, Curb Costs.* National Defense, March 1998, p24-26.

Evers, Stacey, *GNAT-750 may raise profile of UAVs.* Aviation Week & Space Technology 7 February 1994: p 54-55.

FMFM 3-22-1, *UAV Company Operations.* U.S. Marine Corps. 4 November 1993.

Fulghum, David A., *Gull-Wing UCAV For U.S. Aircraft Carriers.* Aviation Week & Space Technology 16 June 1997: p. 56-57.

Fulghum, David A., *Navy Study Tackles 21st Century Threats.* Aviation Week & Space Technology 10 November 1997: p. 32-33.

Fulghum, David A., *Navy Wants UCAVs For Carrier Use.* Aviation Week & Space Technology 2 June 1997: p. 55.

Fulghum, David A., *Outrider makes Pentagon uneasy.* Aviation Week & Space Technology 3 February 1997: p 32.

Fulghum, David A., *Outrider UAV tackles Army, Navy requirements.* Aviation Week & Space Technology 22 July 1997: p 70-71.

Fulghum, David A., *Payload, Not Airframe, Drives UCAV Research.* Aviation Week & Space Technology 2 June 1997: p. 51-54.

Grieco, Anthony (OUSD (A&T)), *UAV/UCAV Payloads Conference: Payloads and Tomorrow's Battlespace.* 11-12 February 1998.

Gugliotti, Jackie. *UAV White Paper.* Virtual Prototypes. 31 October 1997.

Kreider, David, *Tactical Control System Overview.* JPO UAV (Brief). 9 July 1997.

Krekich, A. VADM, USN, *Tactical Control System.* COMNAVSURFPAC Brief. 17 September 1997.

Kumar, Rajesh, Sqd Ldr, *Tactical Reconnaissance: UAVs verses Manned Aircraft.* USAF Air Command and Staff College. March 1997.

Larson, Dean, *Preliminary Ideas for a Cost/Benefit Analysis on the Maritime Utilization of UAVs.* CAN Study for OPNAV N-88I. 28 July 1997.

NATO Brussels (Belgium). *NATO Staff Requirements for a NATO Maritime UAV System.* Project Group 35 (NATO Unclassified). 31 July 1996.

NATO Brussels (Belgium). *Project Group 35 on a Maritime UAV System.* Strategy Paper (NATO Unclassified). 20 October 1997.

Naval Aviation... Forward From The Sea. Office of Naval Operations Director, Air Warfare, N88. 1997.

Naval Surface Warfare Center Dalgren Division (NSWCDD), *Tactical Control Station (TCS) Demonstration Plan for USS Tarawa (LHA-1) Fleet Exercise 98-1 M.* PEO (CU/UAV) Joint Project, 30 September 1997.

Naval Warfare Innovation Concept Team Reports. Chief of Naval Operations Strategic Studies Group XVI. June 1997.

Navy, Marine Corps Near Completion of VTOL UAV Requirements. Aerospace Daily 23 January 1998:p 111.

Office of Naval Research (ONR 351), *TACAIR Concept of Operations and Technology Plan for Communications and Decision Aids.* March 1997.

Office of the Secretary of Defense, Defense Airborne Reconnaissance Office. *UAV Battle Laboratory Symposium.* Briefing slides. 5 March 1997.

Office of the Secretary of Defense. *Tactics and Technology for 21st Century Military Superiority.* Defense Science Board 1996 Summer Study Task Force. October 1996.

Office of the Under Secretary of Defense (Acquisition & Technology) Defense Airborne Reconnaissance Office (DARO). *UAV Annual Report 1997.* 6 November 1997.

Operational Concept Document (CONOPS) for the Medium Altitude Endurance (MAE) Unmanned Aerial Vehicle (UAV) "Predator". U.S. Atlantic Command. September 1995.

Report on UAV Technologies and Combat Operations. USAF Scientific Advisory Board Army Science. November 1996.

Ryan, George R., *Electromagnetic Environmental Effects: Research, Development, Test and Evaluation.* Naval Air Warfare Center Aircraft Division, Patuxent River. 1997.

Sosa, Arthur J., LCOL, USA. *Unmanned Aerial Vehicles – Promises and Potential.* U.S. Army War College. 7 April 1997.

Swanson, Roger L., *UAVs and Data Links.* Information Directorate, US Air Force Research Laboratory. 21 November 1997.

Tactical Control Station (TCS) Intercom Equipment Hardware Performance Specifications. PEO (CU/UAV) Joint Project. 24 February 1998.

Tactical Control Station (TCS) Systems Integration Contract Statement of Objectives. PEO (CU/UAV) Joint Project. 14 January 1998.

Tam, Daniel, and Michael McGinnis, Anh Lu, John Meloling, Shing Li. *JTUAV/SV Topside EMC Analysis of the USS Tarawa (LHA-1).* Naval Sea Systems Command (PMS-335-P25). December 1995.

Technology for the United States Navy and Marine Corps, 2000-2035. Volume I. National Research Council. 1997.

U.S. Army Communications Electronics Command, *Proceedings of the UAV Joint Technology Steering Committee.* 17-19 September 1996. Vol. II.

Williamson, Michael, CDR, *Navy Perspective on UCAV.* UAV/UCAV Payloads Conference, 11-12 February 1998.

Williamson, Mike, CDR, USN, Dr. John Fisher, and Julieta Booz, *NAVY UCAV.* Advanced Development Project Office (ADPO) Brief. 1997.

Zaloga, Steven J., *UAV Military future deemed 'promising'.* Aviation Week & Space Technology 13 January 1997: p 89-97.

APPENDIX C: ACRONYMS

ACTD	Advanced Concept Technology Demonstration
AIMD	Aircraft Intermediate Maintenance Department
ALRE	Air Launch and Recovery Equipment
AMX	Air Mobility Express
AV-8B	Harrier Aircraft
AVO	Air Vehicle Operator
AWACS	Airborne Warning and Control System
BDA	Bomb Damage Assessment
BLOS	Beyond Line of Sight
BSFC	Brake Specific Fuel Consumption
C2	Command and Control
C4I	Command, Control, Communications, and Intelligence
C4ISR	C4, Intelligence, Surveillance, and Reconnaissance
CAF	Commander, Assault Forces
CARS	Common Automatic Recovery System (UAV)
CATF	Commander, Amphibious Task Force
CH-46	Sea Knight, Helicopter
CI	Compression Ignition
CJCS	Chairman, Joint Chiefs of Staff
CLF	Commander Landing Force
CNO	Chief of Naval Operations
COD	Carrier Onboard Delivery
CONUS	Continental United States
COTS	Commercial Off the Shelf
CSV	Capacity Selector Valve
CV	Aircraft Carrier
CVBG	Carrier Battle Group
CVN	Aircraft Carrier (nuclear)
CVX	Aircraft Carrier (proposed/future)
D&V	Demonstration & Validation

DARO	Defense Airborne Reconnaissance Office
DLA	Defense Logistic Agency
DSCS	Defense Satellite Communication System
DTAV	Defense Total Asset Visibility
E&MD	Engineering & Manufacturing Development
E3	Electrical, Electronic and Electromagnetic
EMC	Electromagnetic Compatibility
EMCON	Emission Control
EMI	Electro-Magnetic Interference
EMV	Electromagnetic Volt
EO/IR	Electro-Optic/Infra-Red
FCLP	Field Carrier Landing Practice
FDC	Fuel/Defuel Cart
FOD	Foreign Object Damage
GA, ASI	General Atomic, Aeronautical Systems Inc.
GCCS	Global Command and Control System
GCS	Ground Control Station
GDT	Ground Data Terminal
GPC	Ground Power Cart
GSE	Ground Support Equipment
HERO	Hazards of Electromagnetic Radiation to Ordnance
HVAC	Heating, Ventilation and Air Conditioning
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
ILS	Instrument Landing System
JBS	Joint Broadcast System
JPO	Joint Program Office
JTF	Joint Task Force
LFOC	Landing Force Operations Center
LHD/LHA	Amphibious Assault Ships
LOS	Line of Sight
LSO	Landing Signal Officer

MILSAT	Military Satellite
MLS	Military Logistics Support
MLS	Multi-Level Security
N85	Deputy Chief of Naval Operations, Director, Expeditionary Warfare
N88	Deputy Chief of Naval Operations, Director, Air Warfare
NAEC	Naval Air Engineering Center
NAMP	Naval Aircraft Maintenance Program
NAST	Naval Air Systems Team.
NATOPS	Naval Air Training and Operations Manual
NAVAIRSYSCOM	Naval Air System Command
NAWC-AD	Naval Air Warfare Center, Aircraft Division
NAWCADWAR	Naval Air Warfare Center Aircraft Division, Warminster, PA
NEC	Naval Electronics Center
NLT	Not Later Than
NPV	Non-Piloted Vehicle
OBRP	On Board Repair Parts Package
OEM	Original Equipment Manufacturer
ONI	Office of Naval Intelligence
OPNAV	Office of the Chief of Naval Operations
OT&E	Operational Test and Evaluation
PMA 251DT	Program Manager--Aircraft Launch and Recovery
PMA-263	Program Manager-Unmanned Aerial Vehicles
RF	Radio Frequency
ROM	Rough Order of Magnitude
RSTA	Reconnaissance, Surveillance, Targeting and Acquisition
RPV	Remotely Piloted Vehicle
SAR	Synthetic Aperture Radar
SATCOM	Satellite Communications
SEAD	Suppression of Enemy Air Defenses
SEMCIP	Shipboard Electromagnetic Compatibility Assessment
SHF	Super High Frequency

SSN	Nuclear Attack Submarine
TCS	Tactical Control System/Station
TEMDU	Temporary Duty
TOD	Tail Over Deck
TSII	Trojan Spirit II
TVRO	Television Receive Only
UA	Unmanned Aircraft (collective term for all classes
UAV	Unmanned Air Vehicle
UCAV	Uninhabited Combat Air Vehicle
UHF	Ultra High Frequency
VERTREP	Vertical Replenishment
VFR	Visual Flight Rules

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The Naval Sea Systems Command (NAVSEA) CVX Program Office, PMS-378, is conducting a series of trade-off studies to provide the necessary inputs for the creation of the Operational Requirements Document (ORD) for the Tactical Aviation (TACAIR) sea-based platform for the 21st century, the CVX. SSC San Diego, UAV Project Office, has been assigned two of these studies. This study is the second of the two studies, addressing general operational and physical design characteristics required to incorporate unmanned aerial vehicles (UAVs) organic to CVX operations. Analysis includes both operations from a detachment standpoint (four airframes) and from a squadron standpoint (12 airframes). Potential impact areas include CVX deck structure, launch capabilities, recovery methods, maintenance spaces, storage spaces, personnel living spaces, command and control spaces and workstations, communications and data transmission paths, and ship antennae requirements.

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